SUSTAINED PRODUCTION OF REVEGETATED MINED LANDS AS INFLUENCED BY NITROGEN FERTILIZATION, TOPSOIL DEPTH, AND MULCHING PRACTICES[1]

by

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Abstract. Cultural practices used in reclamation can have a significant effect on the long-term success of revegetated mined lands in arid areas. Topsoil depth, mulch method, and N-fertilizer management practices were evaluated to determine their effects on the long-term production of a revegetated mined site. Production exhibited a significant N-fertilizer management by mulch by year interaction. Seeded species production was significantly greater for 30% of the comparisons (both mulch types) with the single N-application (268 kg N/ha) compared to annual, lower applications (67 kg N/ha) and the remaining comparisons exhibited no differences between the N-management treatments. The single, higher N-application avoids the cost of repeated smaller yearly applications and supplies the N needs for sustained production of the revegetated plant community. Topsoil depth had a greater effect on forage production the first 3 years after establishment than it did in later years (4-5 years). Forage production was not significantly increased by topsoil depths in excess of 40 cm. Production of seeded species was greater when established in a standing-grain stubble compared to a crimped-straw mulch. The stubble-mulch demonstrated long-term benefits resulting from initial improved seedling establishment. These findings demonstrate the importance/benefits of cultural practices in the successful revegetation of mined lands.

Additional Key Words: Cultural practices, stubble-mulch, straw mulch, reclamation

Introduction

Extraction of uranium, bentonite, and coal results in major land disturbance in the Northern Great Plains. Most of this land is rangeland used for forage production for grazing livestock and wildlife. Current laws require that these lands be returned to a productivity level equal to or greater than that prior to mining. These laws also

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require that soil resources be removed before mining and redistributed over the reconstructed landscape. Topsoil depth, mulching, and fertilization can play a significant role in the revegetation of mined lands. Studies in North Dakota, Colorado, and Wyoming have shown that optimum topsoil depth depends on soil and spoil characteristics and climate (Power et al. 1981; Barth and Martin 1982; McGinnies and Nicholas 1980). Cultural practices such as mulch and fertilization have also been shown to benefit revegetation success (Power et al. 1978; DePuit et al. 1978; Schuman et al. 1980).

The purpose of this research was to evaluate the effect of topsoil depth, mulching, and fertilization on the establishment and productivity of revegetated mined lands. Topsoil depths of 0-60 cm and crimped-straw vs stubble-mulch were evaluated. A single N-fertilizer application (268 kg N/ha) was compared to 4 annual applications (67 kg N/ha) to evaluate N-management effects on forage production.

Methods and Materials

Field plots were established in the spring of 1977 at the Pathfinder Mines Corporation uranium mine near Shirley Basin in southcentral Wyoming. Elevation at the research site is 2,195 m and the average annual precipitation in 228 mm. The annual frost-free period averages 88 days.

Topsoil used in reconstruction was a Borollic Haplargid of the fine-loamy mixed family (Young and Singleton 1977). Topsoil was spread over regraded overburden in a wedge shape, ranging in depth from 0 to 60 cm. Topsoil was direct-placed rather than using stockpiled topsoil. Overburden consisted of a 1 m layer of White River geologic material covering Wind River formation material. The White River material consisted of bentonitic arkosic sands interbedded with fine silts and montmorillonitic clays. The Wind River formation is characterized by high silt and clay content with scattered lenses of arkosic sands in the upper portion of the formation. The overburden was sloped so that placement of the topsoil wedge resulted in a level surface with topsoil depths ranging from 0 to 60 cm. Overburden was ripped before topsoiling. Selected physiochemical characteristics of the topsoil and White River overburden are shown in Table 1.

Topsoil was deep-ripped on 60 cm centers, disked and seedbed prepared by cultipacking. Before disking, ammonium nitrate and treble superphosphate (67 kg N/ha and 67 kg P/ha) were broadcast on the entire experimental plot area. Twenty 4.9 x 45.7 m plots were established on the area. Ten randomly selected plots were seeded to barley (Hordeum vulgare L.) in April 1977, at the rate of 50 kg/ha. The barley was allowed to mature, producing a stubble height of 20 to 25 cm, resulting in an average aboveground biomass of 1.0 Mg/ha. Because of climate and growing season, the barley produced only minimal seed; therefore, competition from volunteer plants was not a problem. However, mowing can also be used to prevent seed development and achieve desired stubble height. The remaining 10 plots were fallowed during the

Table 1. Selected physiochemical properties of topsoil and overburden used to construct research plots, Pathfinder Mines Corp., Shirley Basin, WY.

Parameter	Topsoil	Overburden
pH	7.2	7.0
EC (dS/m)	2.5	0.4
C (%)	1.1	0.1
Kjeldahl-N (ug/g)	900	180
$NaHCO_3$-P (ug/g)	4.4	0.7
Water Soluble Cations (meg/l)		
Na^+	9.4	2.4
K^+	0.8	0.2
Ca^{++}	12.6	1.1
Mg^{++}	1.8	0.4
Sand (%)	57	45
Silt (%)	30	38
Clay (%)	13	17
Saturation percentage (%)	39	58

season. In October 1977, all plots were drill seeded with a mixture of western wheatgrass (Agropyron smithii Rybd.), thickspike wheatgrass [A. dasystachyum (Hook.) Scribn.], slender wheatgrass [A. trachycaulum (Link) Malte], and green needlegrass (Stipa viridula Trin.). Each species represented 3.9 kg/ha pure live seed in the total seeding rate. The barley stubble plots were direct-seeded and the fallow plots were mulched with 5 Mg/ha of barley straw after seeding. The straw was crimped into the soil in two directions.

Since research has shown that N is generally a limiting factor in forage production on natural and re-seeded grasslands (Power and Alessi 1971; DePuit et al. 1978), an N-management objective was added to this study in 1979. In the spring of 1979, 5 stubble and 5 crimped-straw plots were fertilized with a single 268 kg N/ha application. The remaining 5 stubble and crimped-straw plots were fertilized at 67 kg N/ha. The plots that received the lower rate of N were fertilized with an additional 67 kg N/ha in the spring of 1980, 1981, and 1982.

In the spring of 1978, seedling emergence was evaluated (Schuman et al. 1980); however, limited growth during the establishment year prevented collection of production data. Production sample sites were established on each plot at topsoil depths of 0, 20, 40, and 60 cm. Sample sites were moved each year. Forage production was determined by clipping at ground level all vegetation within a 0.18 m^2 quadrat. Previous year's growth was separated from the current year's growth. Plant material was separated into seeded and non-seeded species, oven-dried (60°C) and weighed. Forage production was sampled in 1979-1983, when the majority of the species approached reproductive maturity, generally in mid-July.

The entire study area was fenced to exclude grazing by domestic livestock.

Analysis of variance was used to determine significance of main effects and interactions, and mean separation was accomplished by least-significant-difference. All treatment effects were evaluated at the 0.10 level of probability.

Results and Discussion

Mulch Effects

Seeded species forage production (1979-1983 average) at the 40 and 60 cm topsoil depth was significantly greater for grass established with stubble-mulch compared to that established using crimped-straw mulch (Table 2). This probably resulted from the greater seedling establishment that occurred on the stubble-mulch treatment in 1978 (Schuman et al. 1980). Non-seeded species production was significantly lower for the stubble-mulch treatment compared to the crimped-straw mulch at all topsoil depths except 20 cm. The response observed for the non-seeded species is probably related to competition by the seeded species. Non-seeded species production included foxtail barley (Hordeum jubatum), Russian thistle (Salsola kali), lambsquarter (Chenopodium album), fireweed summercypress (Kochia scoparia), tumbling hedgemustard (Sisymbrium altissimum), Poa spp. and prairie junegrass (Koeleria cristata). The benefits of the stubble-mulch during establishment continues to be reflected in the subsequent years' production. Ries et al. (1988) and Schuman et al. (1980) demonstrated that cultural practices resulting in greater seedling establishment can significantly improve production in subsequent years.

Topsoil Depth Effects

Seeded species production was significantly greater at the 40 and 60 cm topsoil depths from 1979-1982; however, in 1983, the greatest production occurred at the 0 and 40 cm topsoil depths (Table 3). Even though greater production occurred on the 0 cm topsoil treatment than on the 20 and 60 cm topsoil treatments in 1983, the forage production range was only 192 kg/ha that year. In previous years, the production varied from 482 to 608 kg/ha over the various treatments. Three years of above-normal precipitation may account for the varied production response observed in 1983 (Table 4).

Non-seeded species production was generally greater in the 0 and 20 cm topsoil treatments the first 3 years; however, this trend was not consistent in 1982 and was reversed in 1983.

The 1983 production (both seeded and non-seeded species) response to topsoil depth is not fully understood; however, it should not be interpreted that topsoil replacement is unnecessary. Preliminary unpublished data collected in 1989 by the authors indicate that the mineralizable nitrogen and microbial biomass of the non-topsoil treatment are significantly lower than those of the topsoil treatments indicating

Table 2. Seeded species and non-seeded species production (averaged across N-fertilizer management and years) as influenced by mulch type at four topsoil depths at a reclaimed mine site, Shirley Basin, WY, 1979-1983.

Production by Mulch Type

Topsoil Depth	Crimped-Straw Mulch: Seeded Species	Crimped-Straw Mulch: Non-seeded Species	Stubble-Mulch: Seeded Species	Stubble-Mulch: Non-seeded Species
cm	kg/ha			
0	490	619	557	479
20	562	495	517	596
40	750	536	972	296
60	701	735	960	461

$LSD_{0.10}$ = 101 to compare values within a topsoil depth for seeded species; 97 to compare values within a topsoil depth for non-seeded species.

Table 3. Seeded species (S) and non-seeded species (NS) production (averaged across mulch type and N-fertilizer management) as influenced by topsoil depth over time at a reclaimed mine site, Shirley Basin, WY, 1979-1983.

Forage Production

Topsoil Depth	1979		1980		1981		1982		1983	
cm	kg/ha									
	S[1/]	NS[2/]	S	NS	S	NS	S	NS	S	NS
0	180	448	274	689	410	1115	656	332	1097	159
20	372	243	356	370	446	1133	483	549	1039	431
40	445	323	689	245	968	605	1091	222	1112	684
60	671	408	756	189	984	952	823	467	920	974

[1/]S = Seeded species; NS = Non-seeded species

$LSD_{0.10}$ = 134 to compare among topsoil depths within a year for seed species (S); 142 to compare among topsoil depths within a year for non-seeded species (NS).

Table 4. Monthly precipitation during growing season, annual precipitation, and average precipitation, Shirley Basin, Wyoming.

YEAR	MONTH					
	April	May	June	July	August	Annual
1978	42	69	20	24	29	266
1979	9	14	12	20	20	157
1980	4	54	2	18	30	167
1981	12	92	4	51	13	243
1982	10	39	51	70	21	257
1983	24	24	57	57	20	279
6-year mean	17	49	24	40	22	228

the absence of or limited sustainable nitrogen cycling.

Fertilizer Response

Production (both seeded and non-seeded species) exhibited a significant N-fertilizer management by mulch by year interaction (Table 5). Even though the 3-way interaction was significant, only a few of the specific comparisons were found to be significant. Lack of consistent significant responses to a given treatment or treatment combination are influenced by the high degree of variability in the data as evidenced by the large LSD values. However, some important and definite trends are evident in the data.

Seeded species production was significantly greater in 1981 and 1983 for the straw mulch, and in 1982 for the stubble-mulch with the single N-application compared to annual applications when evaluated over the 5 years. In the remaining seven comparisons there were no significant differences between N-fertilizer management treatments.

Seeded species production also exhibited a general increase over time, with 1981-1983 production being significantly greater than that of earlier years. The responses to the N and mulch observed from 1981 to 1983 were influenced by the greater precipitation received in those years (Table 4). The standing stubble-mulch resulted in significantly greater seeded species production in 40% of the comparisons; however, 80% of the comparisons actually exhibited greater production for the stubble-mulch treatment.

Non-seeded species production exhibited a rather random response to N-fertilizer treatment. However, non-seeded

Table 5. Seeded species and non-seeded species, production (averaged across topsoil depth) as affected by mulch practice and N-fertilizer management over a 5-year period on reclaimed mined lands, Shirley Basin, WY, 1979 - 1983.

		YEAR									
		1979		1980		1981		1982		1983	
		Nitrogen Fertilizer Management[2/]									
Production Component	Mulch[1/] Type	N_1	N_4	N_1	N_4	N_1	N_4	N_1	N_4	N_1	N_4
		kg/ha									
Seeded Species	M1	366	351	501	416	688	495	669	772	1100	903
	M2	489	461	568	591	760	865	905	707	1012	1154
	$LSD_{0.10}$ = 168 (N-management within mulch and year); 146 (mulch practice within N-management and year); 150 (year within N-management and mulch)										
Non-seeded Species	M1	529	306	536	344	954	1196	367	439	623	670
	M2	288	298	373	242	946	709	291	472	368	590
	$LSD_{0.10}$ = 164 (N-management within mulch and year); 155 (mulch practice within N-management and year); 159 (year within N-management and mulch)										

1/ M1 = crimped straw; M2 = standing stubble.

2/ N_1 = 268 kg N/ha single application; N_4 = 67 kg N/ha/yr (1979 through 1982).

species production was higher for the crimped-straw treatment than for the stubble-mulch treatment. Although 90% of the straw mulch treatments showed higher non-seeded species production compared to the stubble-mulch, only 40% were statistically significant.

Summary

Use of a grain stubble during seedling establishment compared to crimped-straw mulch resulted in significantly greater forage production by seeded species at 40 and 60 cm topsoil depths and significantly lower non-seeded species production at all topsoil depths except 20 cm. Topsoil depths of 40 or 60 cm resulted in significantly greater seeded species production than 0 or 20 cm topsoil depths in 4 of 5 years. Seeded species production was not increased between the 40 and 60 cm topsoil depth, except in the year after establishment. Non-seeded species production was greater at 0 cm topsoil than at greater depths the first 3 years after establishment, but was inconsistent during the last 2 years of the study. Nitrogen-fertilizer management (timing and rate) had limited effects on seeded species production, and where it did significantly influence production, the higher, single N-application exhibited greater production than lower annual N-applications.

These findings indicate that significant cost savings can be achieved by using grain stubble-mulch and a single, larger N-fertilizer application to ensure adequate fertility of the revegetated community. A single N-application also avoids the expense (labor and equipment) of repeated annual N-applications. Nitrogen-fertilizer management practices must take into account soil and hydrologic conditions to prevent possible surface and ground water contamination.

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